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Factors influencing environmental stewardship in U.S. agriculture: Conservation program participants vs. non-participants

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ABSTRACT

United States Department of Agriculture (USDA) conservation policy has increasingly shifted from a traditional land-retirement focus to greater emphasis on producer adoption of working-land conservation practices. This research made use of USDA integrated field/farm surveys, the Conservation Effects Assessment Project (CEAP) and Agricultural Resources Management Survey (ARMS), to (1) enhance understanding of operator, field, farm, economic, and environmental characteristic differences between conservation program participants and non-participants across a farm typology, and (2) to enhance understanding of the relative importance of these factors on influencing farm stewardship intensity in corn and wheat production, i.e., how these factors influence differences in producer adoption of alternative levels of land and pest-management practices between conservation program participants and non-participants. The research used a cost-function acreage-based technology adoption model to examine farm stewardship differences. Results indicate that program non-participants invest more heavily in land conserving and pest-management practices than program participants. Relative prices, structural, and socio-environmental factors play significantly different roles across crops, and between conservation program participants and non-participants, in their influence on producer adoption decisions for land and pest-management intensity. The environmental effectiveness and cost efficiency of conservation programs will likely improve when their implementation more explicitly recognizes farm heterogeneity as well as differences in farmer motivations for stewardship investments. Recognizing these differences can help improve targeting of conservation incentive structures.

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Introduction

The U.S. Department of Agriculture (USDA) conservation programs have historically emphasized cropland retirement. Recent programs emphasize working-land conservation, specifically through the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP). Funding for working land conservation programs increased from $174 million in 2000 to roughly $2.4 billion in 2012 (Claassen, 2014). Working-land programs assist farmers with implementing and maintaining conserving land-management practices such as conservation tillage, crop rotations, cover crop management, enhanced nutrient management, precision agriculture, irrigation water management, pest management, and various conservation structural practices such as strip cropping, terraces, and stream-side herbaceous buffers (Lambert et al., 2007a,b; Schaible et al., 2009). Working-land conservation goals also benefit from USDA participation in Federal and State/local partnership agreements focusing on watershed-scale resource and environmental policy issues that go beyond the farm. Partnership agreements implement land, water, and habitat conservation activities on both working farmland and other lands that reduce salinity problems, improve water quality and supply, enhance fish and wildlife habitats, and promote environmental protection and compliance with Federal, State, and local regulations. With enactment of the Agricultural Act of 2014, the USDA now participates in watershed, State, and multi-State

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financial assistance-based conservation partnerships through the Regional Conservation Partnership Program (RCPP).[4]

Since 2004, the environmental effectiveness of USDA conservation programs has been evaluated by USDA's Natural Resource Conservation Service (NRCS) through its Conservation Effects Assessment Project (CEAP). USDA's vision for CEAP focuses on "*enhanced natural resources and healthier ecosystems through improved conservation effectiveness and better management of agricultural landscapes*" (USDA-NRCS, 2013a). The project's primary data source is a farmer survey of field-level conservation practices and program participation (for survey years 2003–2006), integrated with environmental data at National Resources Inventory (NRI) data points. We hypothesize many factors other than program incentives drive the environmental performance of U.S. agriculture. Good land stewardship and its environmental benefits often make good business sense even without program participation (Smith and Weinberg, 2004; Hopkins and Johansson, 2004; Robertson and Swinton, 2005; Bowman and Zilberman, 2013). In addition, for some producers non-financial concerns, such as moral and social values can be motivating factors encouraging the willingness to forgo some profits when adopting conservation practices (Chouinard et al., 2008; Mzoughi, 2011; Sheeder and Lynne, 2011).

In an effort to better understand farmer motivation related to conservation practice adoption, the USDA conducted a pilot national survey integration program during 2004 and 2005, the Conservation Effects Assessment Project – Agricultural Resources Management Survey (CEAP-ARMS). CEAP-ARMS integrated CEAP information [National Resource Inventory (NRI) data on field-level physical (environmental) characteristics and CEAP production practice and conservation program participation data] with USDA ARMS data on cost-of-production, operator, farm household, and farm economic/resource data (Lambert et al., 2007c). By linking these surveys, USDA intended to provide a clearer understanding of the differences between program participant and non-participant behavior to help it modify the design, implementation, and monitoring of conservation programs, as well as revise over time its environmental policy objectives — assumed to be inclusive of farm-related ecological services, such as improving air and water quality from changes in crop and farm resource management; reducing greenhouse gases (GHG) and enhancing carbon sequestration through the use of methane digesters, conservation tillage or no-till, and by converting cropland to grasslands and forests; preserving wetlands; and enhancing wildlife habitat (Ribaudo et al., 2008; Marshall and Weinberg, 2012; Horowitz and Gottlieb, 2010). In addition, USDA, in compliance with the Food, Conservation, and Energy Act of 2008 established the Office of Environmental Markets (OEM) designed to facilitate landowner participation in emerging markets for farm ecosystem services, with particular emphasis on measuring the environmental service benefits from conservation and land management activities.[5]

Using the 2004 and 2005 CEAP-ARMS data for wheat and corn production, we first compare operator, field, farm, economic, and environmental characteristics of conservation program participants with non-participants across a farm typology. Secondly, we use an econometric model to examine the relative importance economic, field/farm, resource, and environmental factors have on influencing farmland stewardship intensity by corn and wheat producers, i.e., how producer land and pest-management intensity differs between conservation program participants and non-participants, separately by crop. Based on CEAP-ARMS data, land-management practices include: (a) the use of crop rotations; (b) conservation tillage (no-till, strip-till, ridge till, or mulch till); (c) performing soil nutrient tests; (d) use of variable-rate technology (VRT) in fertilizer and/or seed application; (e) contour and/or strip cropping; and (f) use of GPS-based soils maps of field soil properties for improved crop production management. Pest-management practices includes: (a) scouting for pests; (b) keeping written/electronic records to track field pests over time; (c) comparing of pest scouting data to public threshold data; (d) using biological pesticides and growth regulators; (e) using rotated or tank-mixed pesticides to mitigate against pest resistance; (f) using field mapping to assist in pest management decisions; (g) use of diagnostic lab services for pest identification analysis; (h) use of crop seed varieties resistant to specific pests; (i) adjusting of crop planting/harvesting dates; (j) use of weather data for improved pest applications; (k) altering crop planting locations to avoid pest infestations; (l) use of water-management practices to help in pest management; and (m) use of alternative field cultural practices designed to reduce the spread of pests.

This paper extends use of an agricultural technology adoption framework from two perspectives: (1) it shifts the concept of production technology from the traditional practice-by-practice definition to a production systems (or stewardship intensity) perspective where alternative levels of stewardship intensity (a production technology system) involve producer use of multiple land and pest-management practices; and (2) it applies a cost-function acreage-based technology adoption model to evaluate producer adoption of alternative land and pest-management production systems. The econometric model is estimated using a Generalized Estimating Equations (GEE) procedure to accommodate for correlation across producer production system adoption decisions. As used here, farmland- and pest-management intensity for a crop field (i.e., the level of stewardship) is gauged by the crop acres managed under a set of conserving land- and pest-management practices applied in concert to the field.

The crop-specific models, each jointly estimated with four acreage-based technology adoption equations for program participants and non-participants, respectively, evaluate four production-system based practice decisions representing four land/pest-management production technology intensity classes, ranging (for both land and pest-management) from conventional production practices to the most-conserving practices. Alternative levels of stewardship associated with production technology intensity decisions were assumed to occur on wheat (2004) or corn (2005) fields consistent with the use of: (1) conventional land and pest-management practices; (2) conventional practices but with an emphasis on more-conserving land-management practices; (3) conventional practices but with an emphasis on more-conserving pest-management practices; or (4) more-conserving of both land and pest-management practices. Each model estimates land and pest-management intensity (in acres) across wheat or corn production as a function of normalized input costs (prices), the alternative types of land/pest-management choices available, the presence of field management structures (i.e., conserving irrigation systems and/or soil conservation structures), and covariates reflecting the influence of a variety of field, farm, and environmental characteristics on the adoption decision.

Literature review

A variety of linear logit, probit, tobit, and multinomial logit probabilistic models, generally based on dichotomous choice data have been typically used to evaluate farm technology adoption decisions. Marra and Carlson (1987) found that double-cropping of

[4] For more information on the RCPP program, see the USDA website at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/farmbill/rcpp/.

[5] For more detailed information on USDA environmental objectives and markets, see the USDA-OEM website for "Understanding Environmental Markets," at: http://www.usda.gov/oce/environmental_markets/understanding.htm.

soybeans with wheat in the southeast U.S. did not increase proportionally with farm-size because of differences in farmer attitudes toward risk, while crop price and yield risk factors continued to play an important role in explaining the covariance of farm enterprise returns. Alexander et al. (2003) in assessing farmer decisions for genetically modified (GM) corn and soybeans in Iowa found that a farmer's past experience with GM crops, attitudes about taking risks, and beliefs regarding consumer acceptance of biotech food products, as well as farm size explained decisions to a larger degree than did risk preferences. Keelan et al. (2009) found that early adopters of GM crop technology in Ireland would be farmers with large farm acreage who are specialist crop farmers and who have formal agricultural education together with access to high-quality soils. For Irish farmers, characteristics such as age, land-tenure, and profitability were less important in their adoption decision than farm size. D'Souza et al. (1993) analyzing the adoption of sustainable agricultural practices for West Virginia farmers, found that farm size and the debt/asset ratio were not significant in explaining farmer decisions, but that human capital characteristics such as age and education were significant. They also found that the likelihood of adoption of sustainable agriculture is affected most by the environmental characteristic of whether or not the producer is aware that groundwater contamination exists on the farm. Rahm and Huffman (1984) and Davey and Furtan (2008) assessed the adoption of conservation tillage practices by farmers in Iowa and the prairie region of central Canada, respectively. For Iowa corn farmers, adoption of reduced tillage technology varied widely but was more heavily dependent on soil characteristics, cropping systems, and the size of the farming operation, while a farmer's education level enhanced the efficiency of the adoption decision. For Canadian prairie farmers, conservation tillage adoption was influenced most by local weather and soil conditions, farm size, and the proximity to a research farm, while a farmer's education level was not as important. Adoption of organic farming practices was assessed in several studies. Lohr and Salomonsson (2000) examined the role that subsidies played in enhancing organic agriculture in Sweden, showing that farmers requiring subsidies tend to manage larger less-diversified farms and are generally more concerned with organic inspections, quality, and adequacy of technical advice. Access to more market outlets and information sources were found to be substitutes for higher subsidy levels. Parra and Calatrava (2005) assessed the characteristics of organic olive farms in the south of Spain, finding that they were less productive than their conventional counterparts, that younger operator/managers more involved with management and administration activities, attended more courses, were members of agricultural associations, held a more negative opinion of the use of chemicals, and believed that organic agriculture was more time and effort intensive but would provide greater returns. Isin et al. (2007) evaluated the relative importance of alternative social, farm structural/economic, and producer intellectual/informational factors affecting the adoption of organic dried fig production in Turkey. Younger more educated producers, and producers with more fig production experience were more likely to adopt organic fig production practices. Also, while farm size was not significant, a farm's fig production level was important. The producer organic fig production decision was also influenced by whether the producer was conversant with organic subsidy policies, informed about fig export prices, and knowledgeable on the subject of aflatoxin and its potential impact on fig production. For water-conserving irrigation technology adoption, Caswell and Zilberman (1985) found that higher water costs, the use of groundwater, the production of nuts, and location increased the likelihood of adopting more-efficient drip and sprinkler irrigation by fruit growers in the Central Valley of California. They demonstrated that water price policies could induce adoption of more efficient irrigation systems. Lichtenberg (1989) demonstrated the importance of center-pivot irrigation technology adoption in explaining the shift in crop production for western Nebraska to more water-sensitive crops (particularly maize). Schaible et al. (1991) and Schaible and Aillery (2003) examined irrigation technology transitions for the U.S. Pacific Northwest (PNW) and the mid-Plains States regions, respectively, finding that time-dependent economic influences (normalized commodity prices) were critical in explaining producer transitions to more efficient irrigation systems. For both regions, in the absence of policy-induced conservation incentives, future irrigation technology transitions were found to continue but at a relatively slow to modest pace. However, because the regions differ in their resource endowments (groundwater in the mid-Plains States vs. surface water in the PNW), agro-climatic and cropping systems, different conservation policy and institutional resource-management approaches would be required to promote resource, environmental and social policy goals.

Cooper and Keim (1996), Lichtenberg (2004), and Lichtenberg and Smith-Ramirez (2011) each advanced prior empirical applications when they addressed producer adoption of working-land conservation practices using micro-level data. Cooper and Keim (1996) specified a dichotomous choice approach to evaluate producer willingness to adopt land-management practices assuming randomly pre-assigned bid values; and the practice-based program acreage responsiveness for producers not currently using the practice. Their results demonstrate continued positive adoption rates for these practices by current non-users, but to gain additional adopters would likely be expensive, significantly beyond existing government bid rates (at the time). However, Cooper and Keim did not account for the conservation behavior of farms that did not participate in state and federal conservation programs. Their acreage-response relationships (based on stated-preference data) likely reflect hypothetical behavior rather than actual producer behavior, and were practice-specific rather than farm production system oriented. Lichtenberg (2004) used a dual approach to define latent conservation practice demand relationships from a conceptually specified farm-level land valuation model to estimate practice-specific adoption (demand) equations (based on discrete adoption data) for seven land-management and structural conservation practices for the state of Maryland. He found that producer responsiveness to increases in conservation practice costs differed significantly across alternative practices, and that because of substitutes and complementarity across practices, the efficacy of cost-sharing programs could be improved by taking these characteristics into account. However, use of single-equation estimation did not adjust for bias associated with potentially correlated decision-making. Finally, Lichtenberg and Smith-Ramirez (2011) used a regression model with endogenous switching to evaluate the influence of farm, human capital, topographic, and potential water quality factors on conservation program cost-sharing of adoption of just three structural conservation practices (contour farming, strip cropping, and cover crops) across Maryland farms. In addition, their analysis assessed whether cost-sharing results in expansion of cropland at the expense of land under vegetative cover (slippage), and thereby potentially offsetting reductions in environmental spillovers (i.e., due to increasing aggregate erosion and nutrient runoff, etc. on expanded cropland). Their results indicated that federal/state conservation cost-sharing programs do increase the probability that farms use conservation practices, but that they have little or no influence on the shares of land that Maryland farmers who are already using these practices allocate to them. Secondly, the authors suggest the likely presence of some slippage but could not determine the degree of this offset. Even so, the focus of their land conservation perspective was limited in scope and their analysis did not consider farmer conservation activities as part of a crop production system.

Modeling approach

Conventional probabilistic models have evaluated technology-based acreage share allocation decisions assuming dichotomous choice information, as well as fixed landholdings, and full utilization of land resources (Just and Zilberman, 1983). For these models, technology allocation shares must sum to 100 percent of the assumed fixed landholdings. Therefore, for agriculture, models based on the log odds of choosing an advanced technology over a conventional technology assume that available cropland is fully utilized or cropland is predetermined. However, given that the 2004 and 2005 CEAP-ARMS data is based on continuous revealed preference data for producer acreage allocations, and given that a probabilistic model is not suitable to examine crop-specific technology adoption decisions where crop acreage is not predetermined, this study used a dual approach following Lichtenberg (2004), Kim et al. (2005), and Schaible et al. (2009) to examine the intensity of producer land and pest-management conservation decisions in U.S. wheat and corn production. We use a generalized, cost-function based acreage allocation approach to examine producer crop-specific production practice decisions across four broad land and pest-management technology (intensity) groups (production systems). The dual approach used here also differs from previous technology adoption analyses by endogenizing the differential behavior between conservation program participants and non-participants.

The modeling approach used is based on an extension of the theoretical work by Kim et al. (2005), a modification of the work by Schaible et al. (2006, 2007), and an application of the cost-function technology adoption model specified in Schaible et al. (2008, 2009). The present application differs from Schaible et al.'s (2009) study which used 2004 CEAP-ARMS data to evaluate producer decisions to allocate field acres to *infield or field perimeter conservation structures* for wheat acres. At the time, as a component of USDA EQIP funding, producer adoption of conservation structures was a key USDA conservation policy concern. This paper extends the analysis of conservation structures to a broader array of crop production technologies and their use intensity (as a production system) by conservation program participants and non-participants.

Since passage of the Food, Conservation, and Energy Act of 2008 and subsequent establishment of the Office of Environmental Markets, USDA has broadened the linkage between integrated farm conservation and land management practices (farm production systems) and their environmental benefits (USDA-OEM, 2013). In addition, USDA CEAP studies confirm that evaluating production systems is more likely to increase protection of natural resources across the landscape rather than the traditional practice-by-practice approach (USDA-NRCS, 2013b). Crop production systems, however, vary dramatically across farms and formulation of more effective conservation policy requires insight into explaining this variability.

Both the theoretical model developed in Schaible et al. (2009), as well as the 2004 (for wheat) and 2005 (for corn) CEAP-ARMS data are unique in providing us the opportunity to address this broader agricultural conservation policy issue. This paper examines the factors influencing *farm stewardship intensity* in both corn and wheat production, i.e., the intensity corn and wheat producers adopt a host of farmland and pest management practices as resource-conserving and more ecologically friendly crop production systems.

Both conservation program participants and non-participants are presumed to recognize the changes in output and costs associated with shifting wheat (or corn) acreage from conventional to more conserving land or pest-management practices. The null hypothesis is that the average number of acres associated with each type of land/pest-management technology for wheat (or corn) production by conservation program participants is not different from non-participants. We also maintain that even though a producer-based economic framework can explain the practice adoption behavior of producers, use of onsite socio-environmental data from an integrated data base will improve estimation of adoption behavior and contribute to stronger conservation program analysis by accounting for land heterogeneity (i.e., land environmental characteristics) (Lambert et al., 2007c).

The modeling framework evaluates producer technology adoption decisions by comparing acreage supply functions (derived from dual cost functions) across four land/pest-management production system (technology) groups. For land-management practices, the more-conserving land-management production practices were defined to include fields where the producer practiced either conservation tillage, planted seeds or applied fertilizer using VRT, and also made use of either GPS-based soils maps or nutrient tests. All other fields not identified as being managed with more-conserving practices were classified as using conventional land-management production practices. The more-conserving pest-management production practices were defined to include fields where the producer practiced from 1 to upwards of 7 (out of 12) pest-management practices: keeping written/electronic records to track field pests over time; using biological pesticides and growth regulators; using field maps to assist in pest management decisions; use of diagnostic lab services for pest identification analysis; using crop seed varieties resistant to specific pests; using weather data for improved pest applications; or using water-management practices to help manage pests. Conventional pest-management production practices were identified to include all other crop fields (see the full list of land and pest management practices discussed earlier).

Using these categories, we then defined four broad production technology (intensity) classes: (1) conventional land/pest-management production technology; (2) generally conventional land/pest-management production technology, but with an emphasis on more-conserving land-management practices; (3) generally conventional land/pest-management production technology, but with an emphasis on more-conserving pest-management practices; and (4) most-conserving land/pest-management production technology identified by observations using the more-conserving practices for both land and pest-management.

From a broad theoretical perspective, the modeling approach (derived from Schaible et al., 2009) defined $c(y_{i,p})$ and $c(y_{j,p})$ as per acre crop production cost functions using the ith and jth alternative land and pest-management intensive production technologies by the pth program participation class ($p = 1$ or 2, for conservation program participants or non-participants, respectively), where $(y_{i,p})$ is per acre yield. Also, $y_{i,p}$ is a function of output price, P_y, and inputs, x, where x is a function of input prices w. The model assumes cost minimization and linearly homogeneous production functions. In addition, each input is utilized up to where the value of the marginal products of the kth input equals its unit price, w_k. Schaible et al.'s (2009) theoretical framework is adapted to accommodate crop production systems defined as the jth production technology for the pth participation class, and is represented as follows:

$$A_{j,p}(y_{j,p}) = \exp\left(\alpha_0 + \sum_k \sum_i \beta_{ik} T_i (w_k/P_y) + \sum_{i=1}^{m-1} \gamma_i T_i\right) + \varepsilon_j, \qquad (1)$$

where $A_{j,p}(y_{j,p})$ is acres managed under the jth technology (land/pest-management intensity group) and the pth program participation class; α_o, β, and γ are parameters; T_i is a dummy variable associated with the ith production technology; and ε_j is an independent and identically distributed disturbance term from the normal distribution with an expected mean of zero and constant variance.

Model estimation

The GENMOD procedure in SAS version 9.3 was used to estimate each model for wheat and corn production separately.[6] The system was estimated using the Generalized Estimating Equation (GEE) approach, which allows for arbitrary correlation within subjects or between groups using a variety of covariance structures (Liang and Zeger, 1986). In our case, we assume that the farmer (the "subject effect") is faced with a set of production technology practices which he may choose to implement [i.e., crop field acres associated with alternative intensity levels for land and pest-management practices] (the "within-subject" effects). Because of the trade-offs between production practice intensity levels, the decision to allocate acres to one production technology (intensity level) or another may be correlated. We specify an unstructured working correlation matrix to model the potential correlation between these practice intensity choices (i.e. the correlation matrix structure typically associated with seemingly unrelated regression or multivariate probit models). A log-link function was used to model the acreage supply decisions.

For the wheat (or corn) model, field acreage-supply equations are estimated for the four technology intensity levels. Acreage supply for the *j*th land/pest-management intensity technology, A_j, was constructed by first identifying survey fields (by crop) for two land management and two pest-management production practice categories, specifically: (1) use of conventional management practices, or (2) use of more conserving management practices. Using these definitions, we categorized observations into one of the four land/pest-management technology (intensity) classes. Because acres on which practices are applied vary within and across farms, it is assumed that CEAP-ARMS data, even at the field level, reflect continuous acreage allocation decisions.

For each crop model, field-level producer acreage allocation decisions (for the four land/pest-management intensity levels) were modeled as a function of normalized per-unit input prices for nitrogen, agricultural wages, and diesel fuel. Three technology variables were also delineated: the alternative types of land/pest-management technology choices available, as well as the presence of other field structural characteristics [i.e., variables for conventional/efficient irrigation[7] and soil conservation structures (infield structures, field-perimeter structures, or both)], and a set of exogenous variables reflecting the influence of field, farm, and associated land environmental characteristics on the practice decision. Conservation structures were classified according to whether they were infield structures (including terraces, grass waterways, vegetative buffers, contour buffers, vegetative filter strips, and grade stabilization structures) or field perimeter structures (including hedgerow plantings, stream-side forest and herbaceous buffers, windbreaks and vegetative wind barriers, field borders, and critical habitat planting areas). A wheat or corn field could have no conservation structures, only infield structures, only perimeter-field structures, or both types of structures. Each set of acreage-supply equations were estimated jointly for conservation program participants and non-participants for each respective crop model.

Input prices were normalized using average wheat or corn prices (per bushel) by state. Normalized prices are expected to reflect how farm-level economic factors affect a conservation program participant/non-participant's perception of production profitability for alternative technology. This logic is consistent with Lichtenberg (2004), who based his argument on Caputo (1990), explaining that relative prices in comparative static models capture the expected crop productivity impacts of alternative conservation practices. Variables for technology choices and the presence of other field structural characteristics were defined as (1,0) variables, where 1 defined participation.

Additional covariates controlled for influences of farm size and structure, as well as several environmental attributes on operator decisions to more intensively adopt land and pest-management practices. Farm size and structure were measured as total cropland acres and land tenure (a variable measuring the proportion of acres owned to total farm acres operated). Total cropland acres are hypothesized to measure the influence of farm size on operator decisions.[8] We used four covariates to explain the effects of field/farm-level environmental characteristics. Derived from CEAP-ARMS data, these environmental attributes included the occurrence of gully erosion on the field, whether surface drainage structures were installed, whether the field was next to a water body or wetland, and whether improving the quality of fish and wildlife habitat was a farm concern. Gully erosion and surface drainage are likely indicators of field-level soil fragility. Producer concerns for fish and wildlife habitat and the proximity of a field to nearby water sources are indicators of the potential to improve offsite environmental benefits.

However, to model the assumptions about producer technology decision-making and economic behavior implied by the cost function approach discussed above, we modified Eq. (1) to accommodate the additional technologies and conservation program participation within the context of data structures used for nested or conditional logit regressions. Our model also accommodates the set of exogenous variables capturing additional farm, land-management and socio-environmental characteristics reflecting the spatial heterogeneity of farms across the surveyed wheat and corn production regions. The empirical model is specified as:

$$A_{j,p}(w_k, P_y, d_p, T_j, X_i) = \exp(\alpha_0 + \delta_p d_p + \sum\nolimits_k \beta_{jk}(w_k/P_y) + \sum\nolimits_k \varphi_{jk} d_p(w_k/P_y) + \sum\nolimits_j \gamma_j T_j + \sum\nolimits_i \theta_i X_i) + \varepsilon_j, \quad (2)$$

where $A_{j,p}(w_k, P_y, d_p, T_j, X_i)$ is acres managed under the *j*th land/pest-management (intensity) technology and the *p*th program participation class; P_y is the state-level corn or wheat price; w_k are the per unit costs of input *k* for diesel, labor, or N fertilizer; *d* is a dummy variable indicating if a respondent participated in a conservation program; T_j are the set of alternative land/pest-management (intensity) technologies and variables for the presence of other field structural characteristics; X_i are the additional farm, land-management and socio-environmental exogenous variables capturing spatial field/farm heterogeneity; and (α_0, δ_p, β_j, φ_j, γ_j, θ_i) are parameters. The marginal effect of a change in the relative price of input *k* on acres managed under the *j*th land/pest-management technology and *p*th program participation class is $\partial A_{j,p}/\partial w_k = (d_p \bullet \varphi_{jk} + \beta_{jk})\exp(z)$, where *z* is $w_k{}^*\phi_k$, the expected effect of the *k*th input price for the *j*th technology and

[6] The SAS GENMOD procedure fits models to data with correlated responses by the Generalized Estimating Equations (GEE) method, introduced by Liang and Zeger (1986). For extensive documentation on both, see the SAS website at: http://support.sas.com/documentation/cdl/en/statug/63347/HTML/default/viewer.htm#genmod_toc.htm.

[7] Wheat (or corn) fields were classified according to no irrigation, or irrigated using either conventional or more-efficient irrigation systems. For additional information on irrigation systems and conventional vs. more efficient irrigation, see the ERS website at: http://webarchives.cdlib.org/sw1rf5mh0k/ http://www.ers.usda.gov/Briefing/WaterUse/glossary.htm, and the chapter on *How Efficient is Irrigated Agriculture* in Schaible and Aillery (2012).

[8] In addition to cropland acres, farm sales could likely also serve as an alternative indicator of farm size (potentially reflecting something about farm financial capacity). However, the CEAP-ARMS Phase II data (used to estimate the two crop models) contained information on farm cropland acreage, but not on farm sales.

pth program participation class. The input-price elasticity follows directly as, $\eta_{jk} = [\partial A_j/\partial w_k](w_k/P_y)$.

To estimate this model, two additional adjustments are required. First, because farmers choose to participate in conservation programs, the decision to participate is essentially non-randomly assigned. This decision may be correlated with farm or producer characteristics, and as a result, the estimated effects of participation and non-participation on conservation technology adoption could be biased. Therefore, we test both technology-intensity adoption models (wheat and corn) for potential sample selection bias using the Heckman two-stage procedure (Heckman, 1979). For each crop, stage one uses probit regressions to determine the propensity of producers to participate in a conservation program, given: (1) the intensity of environmental problems associated with the sampled farm field (i.e., whether the field has been designated by USDA's NRCS as "highly erodible," is a wetland, gully erosion occurs on the field, or the field is next to a water body); (2) the intensity of the producer's environmental resource concern for the field (i.e., whether the producer identifies three or more environmental resource concerns as important within the field's conservation plan); and (3) whether the producer is conscientious about wildlife habitat and managing soil and water resources (i.e., whether the producer installs conserving production practices and manages vegetative cover specifically to enhance wildlife on the farm). In addition, two variables are included to scale land ownership effects on the participation decision; total farm cropland acres and farm tenure. In stage two, we use results from the stage one models to estimate separate Inverse Mills Ratios (IMRs) and include them as explanatory variables in the acreage supply equations for each crop model. If the parameter estimates of the IMRs are significant, then sample selection bias exists and the corresponding model parameter estimates are assumed to be corrected for selection bias. The IMR for the wheat model was not statistically significant, but it was significant for the corn model. Therefore, the acreage supply functions for the corn production model were estimated including the IMR adjustment for sample selection bias.

In addition, while conservation program participation may help to explain farm stewardship intensity, it is possible for additional factors to influence a farmer's actual conservation program participation decision while not having a critical influence on farmer acreage-supply decisions across production technology systems. This scenario creates an omitted variable endogeneity issue, often referred to as "unobserved heterogeneity" (Arellano, 2003; Winkelmann, 2008; Wooldridge, 2010). Without adjusting for this issue, our production system acreage-supply parameter estimates could potentially be biased.

To address the issue of unobserved heterogeneity with respect to a farmer's conservation program participation decision, we apply a two-stage instrumental variables approach, discussed for count models from a practical applications perspective by Mullahy (1997) and from a broader theoretical perspective by Terza (1998). For stage one, we conduct a probit analysis of the conservation program participation decision using a set of explanatory variables (z) inclusive of additional instrumental variables measuring broader information content for farmer education and management skills and field environmental concern and intensity. In addition to the variables for relative input prices, farm tenure and farm cropland acres (for farm size) used to explain production system acreage-supply decisions, dummy variables (1,0) reflecting whether farm operators have a college degree, the intensity of environmental problems associated with the field, whether the farmer manages crop rotations and irrigation runoff to enhance the environment, whether the field has a surface and/or subsurface drainage system, the intensity of a farmer's environmental concern for the field, whether nutrient management is included within the farm's conservation plan, and an indicator of a farmer's wildlife-habitat conscientiousness are used to help explain the farmer's conservation program participation decision.[9] In stage two, the probit parameter estimates are first used to generate predicted values for the exogenous conservation program participation variable (x), separately for Models I (wheat) and II (corn). Because conservation program participation was originally measured as a dummy variable (with program participation = 1), probit predicted values are converted to appropriate (1,0) values based on the criteria [if $(z\prime\widehat{\beta}) > 0$ then $\widehat{x} = 1$, else $\widehat{x} = 0$]. Then, the endogeneity-corrected variable $\widehat{x}$ for conservation program participation is used within the second-stage GEE model estimation of farmer acreage-supply decisions across alternative production technology system equations. The acreage-supply functions by production system technology were estimated incorporating the adjustment for unobserved heterogeneity associated with conservation program participation for both the wheat and corn models.

We estimated Models I (for wheat) and II (for corn) using their associated integrated Phase II/NRI CEAP-ARMS data. USDA's National Agricultural Statistics Service provided the survey weights. Because of the complex design of the CEAP-ARMS survey, variances of estimated parameters are calculated based on standards established by USDA-NASS using the delete-a-group jackknife estimator (Kott, 1997; Dubman, 2000) as outlined in El-Osta et al. (2004). This procedure enabled us to make inferences about means of groups in the paired t-tests (Tables 1 and 2) and for the regressions.

Data: USDA's integrated CEAP-ARMS surveys

This study used USDA's CEAP-ARMS for both 2004 wheat production (across 16 states) and 2005 corn production (across 4 states). The CEAP-ARMS integrated two producer-based surveys: (1) the CEAP survey, a National Resources Inventory (NRI) point-based production practice and environmental data survey; and (2) the ARMS survey, a field/farm level production practice, resource use, farm household and farm economic survey.

The Conservation Effects Assessment Project (CEAP), the Agricultural Resources Management Survey (ARMS), and CEAP-ARMS are all surveys conducted by USDA's National Agricultural Statistics Service. ARMS is an annual crop-specific survey based on a list frame sample conducted in three phases: Phase I involves survey planning/design and sample selection; Phase II is a questionnaire that collects field-level production practice, input use, and cost-of-production data, and Phase III is a follow-on questionnaire that collects associated farm-level resource, economic, and operator/household data. CEAP, being NRI-point based, used an area frame sample design. USDA's National Resources Inventory (NRI) is a longitudinal survey of soil, water, and related environmental

[9] The variable for college degree equals 1 if the farm operator has a bachelor of science, bachelor of arts, or graduate college degree; the variable for the intensity of environmental problems with the field equals 1 if the field has been identified by USDA's NRCS as highly erodible land (HEL) or gully erosion exists on the field or the field includes wetland acres or the field is located next to a water body (pond, lake, stream, or river); the variable for crop rotations and irrigation runoff equals 1 if the operator manages farm crop rotations and irrigation runoff to specifically enhance wildlife on the farm; the drainage system variable equals 1 if the field has a surface and/or subsurface drainage system; the variable for nutrient management equals 1 if nutrient management is identified in the farmer's conservation plan for the field; the variable for a farmer's wildlife-habitat conscientiousness equals 1 if the farmer indicates that he/she installs practices and manages vegetative cover on the field to enhance wildlife on the farm; and the variable for farmer resource concern intensity equals 1 if the farmer identifies 3 or more (out of 7) environmental resource concerns in the conservation plan for the field [including concerns about soil erosion caused by wind or by rainfall and runoff; animal waste management; water quality protection (leaching and runoff of nutrients and pesticides); wildlife habitat enhancement; air quality; and drainage].

Table 1
Average field/farm characteristics for 2004 wheat producers, by conservation program participation and by farm-size class.[a]

Field/farm characteristics	Non-participant farms		Participant farms	
	Retired/residential/lifestyle + farming-occupation/low sales farms [sales <$100,000]	Farming-occupation/higher sales farms [sales ≥$100,000]	Retired/residential/lifestyle + farming-occupation/low sales farms [sales <$100,000]	Farming-occupation/higher sales farms [sales ≥$100,000]
General field/farm values	**A**	**B**	**C**	**D**
Percent of farms (horizontal sum = 100)	37.2 CD	30.0 CD[d]	16.4 AB	16.4 AB
Ave. farm acres operated (ac.)	706 BD	2258 AC	1048 BD	2478 AC
Ave. farm wheat acres harvested (ac.)	152 BD	559 AC	176 BD	517 AC
Percent of wheat acres planted (horizontal sum = 100)	29.6 BCD	40.2 ACD	11.9 AB	18.3 AB
Farm tenure ratio (acres owned/acres operated)	.69 BD	.41 AC	.75 BD	.31 AC
Farm financial values				
Ave. total farm value of production ($)	53,212 BD	474,013 AC	102,114 BD	462,172 AC
Ave. farm revenue share from wheat (%)	26.0	26.0	27.0	21.0
Ave. total farm net worth [equity] ($)	489,309 B	1,728,406 AC	721,082 B	1,233,541
Ave. net farm income ($)	2573 B	85,049 A	32,703	8969
Operator characteristics				
Ave. operator age	57 BD	52 A	56	49 A
Percent wheat farm operators with some college (column %)	18.4	28.4	31.8	25.4
Percent wheat farms with primary operator working off-farm (column %)	58.2 BCD	22.9 AD	46.8 A	14.2 AB
Government payments ($/farm)				
Ave. direct government payments	3273 BD	24,107 AC	X[c]	19,059 A
Ave. counter-cyclical payments	2198 BD	5544 AD	8504	9121 AB
Ave. conservation payments (CRP, WRP, EQIP)[b]	2136	4922 AD	10,342	12,187 AB
Ave. loan deficiency payments (LDP's, etc.)	2094 BD	13,733 A	7632	9103 A
Ave. total government payments	4807 BD	34,976 A	X	31,546 A
Agri-environmental values				
Ave. harvested wheat yield (bu./ac.)	47 B	57 ACD	44 B	43 B
Ave. nitrogen applied per treatment acre (lbs./ac.)	53.0 BD	73.6 AC	44.2 BD	80.4 AC
Ave. USLE soil loss (tons/ac./yr.)	3.0	2.0 D	6.0	4.1 B
Percent wheat farms with gully erosion in wheat fields (column %)	12.7	7.8	3.1	8.8
Percent wheat farms with wheat field adjacent to a water body, intermittent stream or wetland (column %)	32.0	28.4 C	21.5 B	35.1
Percent of wheat acres [with HEL acres in wheat field] (column %)	10.5 D	15.4 C	16.2 BD	53.6 AC
Percent of wheat acres [with wetlands in the wheat field] (column %)	8.1	4.4	17.8	1.7

Source: 2004 CEAP-ARMS Wheat Survey (integrated Phase II and III data), Economic Research Service, U.S. Department of Agriculture.

[a] Surveyed States for the 2004 CEAP-ARMS for wheat included WA, OR, ID, MT, ND, SD, NE, CO, KS, OK, TX, MN, MO, IL, MI, and OH.

[b] Conservation payments here, for non-participants and participants, include government payments for all conservation activities, including land retirement from such programs as the CRP and WRP, and for conservation activities for the entire farm that are not included in our definition of participant (which is based on Phase II-based program participation information).

[c] X indicates that there were insufficient observations for these estimates.

[d] Column difference tests were examined for row values based on pairwise two-tailed [Ho: $\beta_1 = \beta_2$] delete-a-group Jackknife t-statistics at a 90 percent confidence level or higher with 15 replicates and 28 degrees of freedom. For each row value, separately for each row, the letters A, B, C, or D indicate the corresponding column value for which the row value is significantly different. Values without a letter indicate no significant difference between that value and its other corresponding row values. A = column 1, B = column 2, etc.

resources designed to assess conditions and trends on non-federal U.S. lands. Data are collected for a field [or primary sampling unit (PSU)] associated with specific latitude/longitude points. NRI data were collected every five years (1982–1997) for 800,000 sample points; while annual NRI data collection now occurs at less than 25 percent of these same sample points.[10]

ARMS, conducted for USDA's Economic Research Service (ERS), is designed to primarily serve information objectives on cost-of-production, farm finances, and crop production practices. Using a streamlined integrated questionnaire, CEAP-ARMS directly linked more detailed production practice, program participation, and field-specific environmental data (for the NRI point) from the USDA-NRCS CEAP questionnaire, with the economic, farm resource, and farm-household and operator characteristic data from ARMS.[11] Later versions of CEAP were not helpful for the analysis in this study,

[10] For additional NRI information, see the USDA website at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri.

[11] For more information on ARMS, see the USDA-ERS website at: http://www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices.aspx; and for CEAP, see the USDA-NRCS website at: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/.

Table 2
Average field/farm characteristics for 2005 corn producers, by conservation program participation and by farm-size class.[a]

Field/farm characteristics	Non-participant farms		Participant farms	
	Retired/residential/lifestyle + farming-occupation/low sales farms [sales <$100,000]	Farming-occupation/higher sales farms [sales ≥$100,000]	Retired/residential/life-style + farming-occupation/low sales farms [sales <$100,000]	Farming-occupation/higher sales farms [sales ≥$100,000]
General field/farm values	**A**	**B**	**C**	**D**
Percent of farms (horizontal sum = 100)	38.9	37.5 CD[d]	7.8 B	15.8 B
Ave. farm acres operated (ac.)	154 BD	1014 AC	283 BD	1181 AC
Ave. farm corn acres harvested (ac.)	57 BD	477 AC	144 BD	508 AC
Percent of corn acres planted (horizontal sum = 100)	8.4 BD	63.0 ACD	3.7 BD	24.9 ABC
Farm tenure ratio (acres owned/acres operated)	.67 BD	.37 A	.79	.45 A
Farm financial values				
Ave. total farm value of production ($)	69,097 BD	358,865 AC	77,076 BD	536,020 AC
Ave. farm revenue share from corn (%)	24.0	38.0 C	65.0 B	39.0
Ave. total farm net worth [equity] ($)	388,082 BD	1,190,144 AC	674,273 BD	1,439,527 AC
Ave. net farm income ($)	12,819 B	105,346 AC	28,945 B	250,846
Operator characteristics				
Ave. operator age	54	52	63	54
Percent corn farm operators with some college (column %)	6.7 B	22.5 ACD	X[c]	12.6 B
Percent corn farms with primary operator working off-farm (column %)	74.2	15.0 CD	35.2 B	17.7 B
Government payments ($/farm)				
Ave. direct government payments	4853 BD	21,960 AC	6573 BD	25,050 AC
Ave. counter-cyclical payments	3521 BD	15,838 AC	3898 BD	17,246 AC
Ave. conservation payments (CRP, WRP, EQIP)[b]	4858	3242	2428	5341
Ave. loan deficiency payments (LDP's, etc.)	8009 BD	25,965 AC	9787 BD	25,889 AC
Ave. total government payments	15,331 BD	59,351 AC	18,077 BD	64,665 AC
Agri-environmental values				
Ave. harvested corn yield (bu./ac.)	125	150	154	156
Ave. nitrogen applied per treatment acre (lbs./ac.)	99.1	134.1	145.2	132.1
Ave. USLE soil loss (tons/ac./yr.)	3.5	3.4	7.7	4.8
Percent corn farms with gully erosion in corn fields (column %)	X	8.5 CD	X	14.1 B
Percent corn farms with corn field adjacent to a water body, intermittent stream or wetland (column %)	17.7	26.5 CD	X	40.8 B
Percent of corn acres [with HEL acres in corn field] (column %)	3.2 D	1.6 CD	3.9 BD	9.3 ABC
Percent of corn acres [with wetlands in the corn field] (column %)	0.0	X	0.0	X

Source: 2005 CEAP-ARMS Corn Survey (integrated Phase II and III data), Economic Research Service, U.S. Department of Agriculture.

[a] Surveyed States for the 2005 CEAP-ARMS for corn included IN, IA, IL, and NE.

[b] Conservation payments here, for non-participants and participants, include government payments for all conservation activities, including land retirement from such programs as the CRP and WRP, and for conservation activities for the entire farm that are not included in our definition of participant (which is based on Phase II-based program participation information).

[c] X indicates that there were insufficient observations for these estimates.

[d] Column difference tests were examined for row values based on pairwise two-tailed [Ho: $\beta_1 = \beta_2$] delete-a-group Jackknife t-statistics at a 90 percent confidence level or higher with 15 replicates and 28 degrees of freedom. For each row value, separately for each row, the letters A, B, C, or D indicate the corresponding column value for which the row value is significantly different. Values without a letter indicate no significant difference between that value and its other corresponding row values. A = column 1, B = column 2, etc.

because after 2005, CEAP surveys emphasize only the collection of field physical data, without field/farm economic data.

CEAP-ARMS followed USDA ARMS sampling and weighting procedures established and implemented by USDA's National Agricultural Statistics Service (NASS). CEAP-ARMS Phase II samples were selected by State and assigned weights (expansion factors) to represent over 90 percent of the acreage for the commodity of interest. Survey sample weights are assigned to allow preparation of population estimates for commodity acreages for the surveyed States. As a result, for this study, the USDA NASS sample observation weights appropriately ensure that analysis results reflect what is occurring across the farm-level wheat and corn production population within the respective study regions.[12] The 2004 Phase II CEAP-ARMS for wheat included a usable sample of 732 NRI point-based, integrated CEAP/ARMS fields planted to wheat across the 16 states of Washington, Oregon, Idaho, Montana, North Dakota, South Dakota, Nebraska, Colorado, Kansas, Oklahoma, Texas, Minnesota, Missouri, Illinois, Michigan, and Ohio, with an overall response rate of 83 percent. The 2005 Phase II CEAP-ARMS for corn included

[12] For more information on ARMS sampling and probability weights, see *ARMS Documentation* on the ERS website at: http://www.ers.usda.gov/data-products/arms-farm-financial-and-crop-production-practices/documentation.aspx.

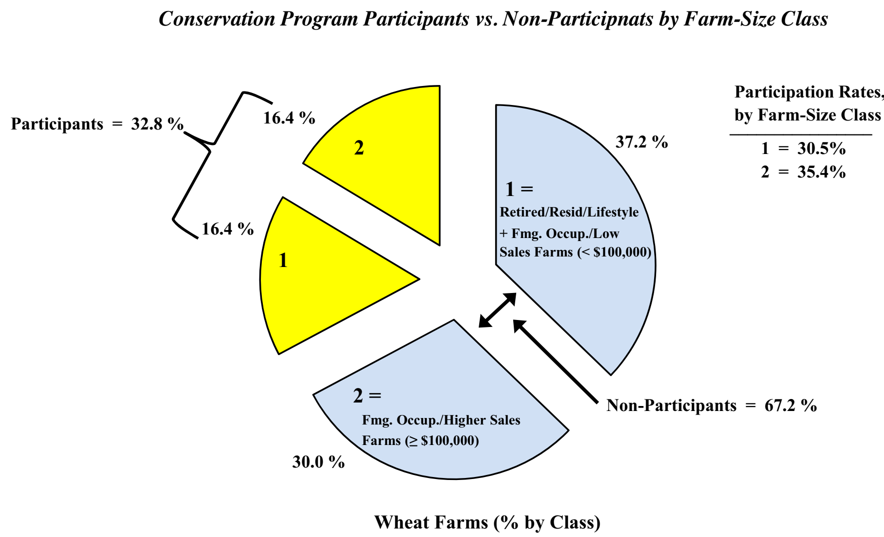

Fig. 1. Percent distribution of the 2004 CEAP-ARMS for wheat.

a usable sample of 380 NRI point-based, integrated CEAP/ARMS fields across Indiana, Illinois, Iowa, and Nebraska, with an overall response rate of 78 percent.

Survey respondents identified as conservation program participants included conservation financial assistance programs in their conservation plan for the field or their field was registered as meeting the requirements for "Highly Erodible Land Conservation Compliance (HELCC)." [13,14] We used the integrated Phase II/NRI/Phase III data separately for each survey (because ERS bases farm size on Phase III household data) to conduct the univariate comparisons of alternative operator and field/farm characteristics between conservation program participants and non-participants by farm-size. The integrated Phase II/NRI/Phase III usable sample was 472 field/farm observations for the 2004 CEAP-ARMS wheat survey and 227 field/farm observations for the 2005 CEAP-ARMS corn survey. Because of the smaller Phase III sample size, we aggregated the ERS farm typology into two farm-size classes for the univariate analysis: (1) retired/residential/lifestyle farms plus farms with total sales <$100,000 and where the operator's primary occupation was farming ("low-sales"); and (2) farms with total sales ≥$100,000 and where the operator's primary occupation was farming ("higher-sales").[15]

Crop prices for wheat and corn, and input prices for nitrogen, agricultural wage, and diesel fuel are USDA-NASS State-level average prices for 2004 and 2005 (USDA-ERS, 2010).

Empirical results

The 2004 CEAP-ARMS survey indicated that about 33 percent of farms growing wheat (in the 16-state study area for wheat) participated in conservation programs (on wheat acres), and that these program participants were evenly split between retired/residential/lifestyle/lower-sales and higher-sales farms (Fig. 1). The participation rates were relatively similar (31–35 percent) between the farm-size classes for wheat production. However, the 2005 CEAP-ARMS indicate that only about 24 percent of the farms growing corn (in the 4-state study area for corn) participated in conservation programs (on corn acres) (Fig. 2). The average participation rate was slightly larger for higher-sales farms growing corn (30 percent) than for the retired/residential/lifestyle/lower-sales farms (17 percent). Most wheat and corn producers in the study areas did not participate in conservation programs on their wheat and corn acreage. While this result may be due in part to program budget limitations, the significance of the result highlights the importance of understanding the characteristic differences between conservation program participants and non-participants.

For both wheat and corn producers, average farm acres differed significantly across farm-size classes, but not always between participants and non-participants by class. For wheat, average operated acres ranged from about 700–1050 acres (283.3–424.9 ha) for retired/residential/lifestyle/lower-sales farms to about 2250–2480 acres (910.5–1003.6 ha) for higher-sales farms (Table 1).[16] However, for corn, farm sizes are somewhat smaller, ranging from about 150–285 acres (60.7–115.3 ha) for lower-sales farms to about 1010–1185 acres (408.7–479.6 ha) for higher-sales farms (Table 2). But for both wheat and corn, retired/residential/lifestyle/lower-sales farms generally owned more land relative to the farmland they operated.

Accounting for differences in marketing years, the 2005 corn producers generally had higher average net farm incomes than did the 2004 wheat producers, but the wheat producers generally had higher farm net worth (equity). In addition, while farm-size differs between participants and non-participants groups, wheat

[13] In addition to HELCC, conservation financial assistance programs included in the definition of "participants" involved the following programs: Conservation Security Program (CSP), Environmental Quality Incentives Program (EQIP), Klamath Basin Water Conservation Program, Ground and Surface Water Conservation Program, Wetlands Reserve Program (WRP), Wildlife Habitat Incentives Program (WHIP), Conservation Reserve Program (CRP), Farmland Preservation Programs, and State cost-share programs. [Program participation information was supplemental survey data provided by USDA's NRCS from program records data and integrated with CEAP-ARMS Phase II survey data by USDA's NASS.].

[14] Phase II data were used to define conservation program participants versus non-participants (for each survey): (1) to ensure maximum use of the larger usable sample sizes for CEAP-ARMS Phase II data when evaluating alternative conservation practice issues; and (2) because the Phase III conservation program participation information applies to the whole farm and not necessarily to the detailed field-level, Phase II conservation practice data linked to the NRI environmental data.

[15] For a detailed definition of the full ERS farm typology, see the ERS Family Farm Report, 2010 Edition (EIB-66) by Hoppe and Banker (2010) at http://www.ers.usda.gov/media/184479/eib66_1_.pdf.

[16] For Tables 1 and 2, where appropriate, metric conversions factors are: 1 acre = 0.4047 hectare; 1 U.S. ton/acre = 2.24 metric tons/ha; 1 bushel/acre (corn 56#) = 62.77 kg/ha; 1 bushel/acre (corn 56#) = 0.0628 metric tons/ha; 1 bushel/acre (wheat 60#) = 67.25 kilograms/ha; 1 bushel/acre (wheat 60#) = 0.0673 metric tons/ha; 1 pound/acre = 1.121 kg/ha.

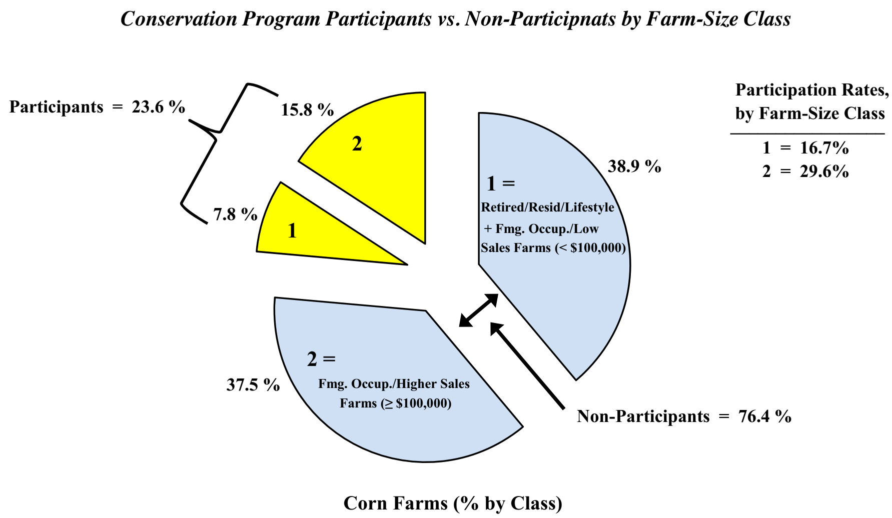

Fig. 2. Percent distribution of the 2005 CEAP-ARMS for corn.

and corn farms were financially similar for each farm-size class across the participation class. However, average net farm income for wheat producers was highest for higher-sales, non-participant farms and, for corn producers, highest for higher-sales, participant farms.

Other respondent/farm characteristics were also notable. For all respondents, farm operators of higher-sales farms were younger than operators of lower-sales farms. For wheat producers, the percent of farm operators having some college education was highest among the lower-sales participant farms, while for corn producers, having some college education was highest among higher-sales non-participants. In addition, the percent of farms where the primary operator also worked off-farm was highest among lower-sales farms for both conservation program participants and non-participants among both wheat and corn producers, but particularly so for corn producers.

On average, farm program payments received were also different between groups. For 2004 wheat and 2005 corn producers, higher-sales farms for conservation program participants and non-participants received more total government payments per farm (Tables 1 and 2). For both crops (and years), while total government payments were generally associated with the average size of direct government and loan-deficiency (LDP) payments, conservation payments (at the farm-level) were generally highest for higher-sales farms among wheat and corn farm participants. The variability in these payments across producer groups, however, was heavily dependent upon participation across a wide variety of USDA commodity and conservation programs. [For more detail on these programs, see the 2007 ERS Economic Research Report (ERR-44) by Claassen et al. (2007)]

From an agri-environmental perspective, wheat and corn producers demonstrate interesting differences. Higher-sales non-participant wheat farms produced higher yields, but higher-sales participant farms produced lower yields even though both groups applied relatively high rates of nitrogen. For corn producers, yields and nitrogen application rates were similar across participant and farm-size groups. An exception is the lower-sales farm group not participating in conservation programs, where corn yields and nitrogen application rates were lower. The similarity in corn yields across the other groups may be an indicator of a relatively more influential role for nitrogen applications in corn production. In addition, lower-sales farms among program participants for both wheat and corn producers had larger average soil loss values [as measured via the Universal Soil Loss Equation (USLE) estimate]. But these farms accounted for only 6.0 and 3.5 percent of planted wheat and corn acres, respectively.

Wheat and corn producers also differed across other field-level environmental attributes. For corn producers, there were a higher percentage of higher-sales farms participating in conservation programs with the following attributes: gully erosion in corn fields; corn fields adjacent to a water body, intermittent stream or wetland; or HEL acres in the corn fields. For wheat producers, a larger percentage of the lower-sales non-participant farms were associated with the presence of gully erosion in wheat fields, while all groups appeared to equally have wheat fields located next to a water body, intermittent stream or wetland. Acreage designated highly erodible was more common among higher-sales farms participating in conservation programs among wheat producers. These differences in agri-environmental characteristics likely help explain differences between wheat and corn producers' use of land and pest-management conservation practices.

For both 2004 wheat producers and 2005 corn producers, farms not participating in conservation programs (on wheat or corn acres, respectively) were the more dominant users of conservation practices, confirming our earlier hypothesis that producers likely do adopt these practices for a variety of economic, social, and environmental stewardship reasons. These farms accounted for 70–71 percent of wheat and corn acres planted in 2004 and 2005, respectively. Not surprisingly, for 2004 wheat farms, both program participant and non-participant farms used conventional more than conserving land-management practices (Fig. 3). However, with respect to pest-management, use of conventional and conserving practices was similar between these groups.

Adoption of land and pest-management practices was different among corn producers (Fig. 4). Among the 2005 corn producers, program participants and non-participants appeared to adopt conventional and conserving land-management practices at similar levels, while more heavily investing in the use of conserving pest-management practices.

Grouping these conventional/more-conserving land and pest-management subgroups into our four broad land/pest-management intensity groups demonstrates that non-participants account for the larger share across all groups. For wheat and corn production, Figs. 5 and 6 demonstrate that while conservation program participants probably make a significant contribution to soil and water conservation, as well as to water quality and ecosystem service goals, non-participants are actually more heavily invested in both conserving land and pest-management practices. Yet, these

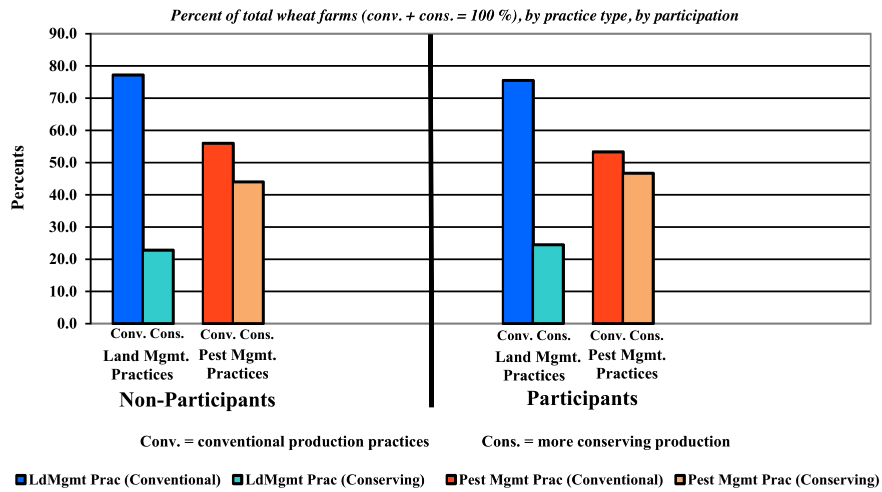

Fig. 3. 2004 Wheat farms by conventional and conserving land and pest-management conservation subgroups.

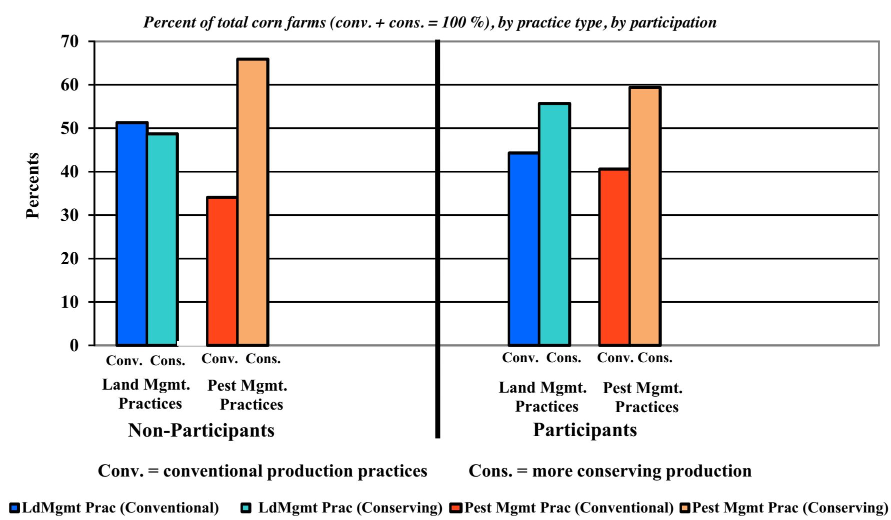

Fig. 4. 2005 Corn farms by conventional and conserving land and pest-management conservation subgroups.

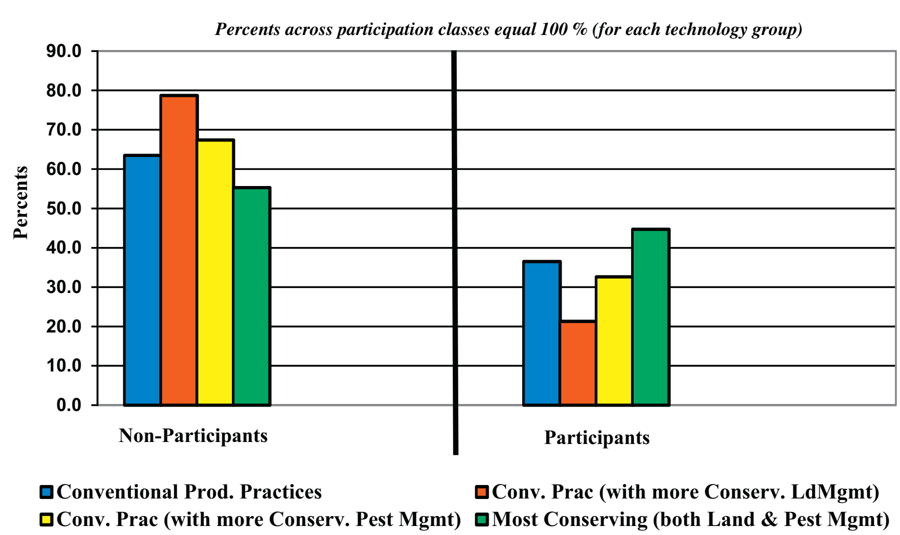

Fig. 5. 2004 Wheat farms classified into four land-management technology groups, by conservation program participation.

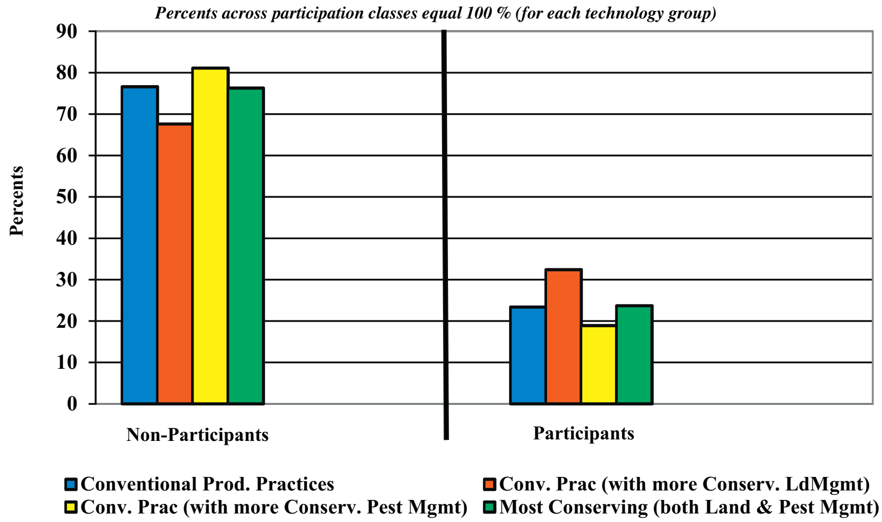

Fig. 6. 2005 Corn farms classified into four land-management technology groups, by conservation program participation.

producers account for the largest portion of producers still using the more conventional practices.

Model estimation results

For both the wheat and corn models, probit regression results (stage one of the Heckman two-stage model) represent the conservation program participation decision rather well. In general, the results indicate that environmental factors play a key role in explaining conservation program participation for both wheat and corn production in the sampled regions, while farm size and structure help to explain participation variation for wheat production but not for corn production. (A more detailed discussion and specific statistical results for this sample-selection bias test are not presented here, but are available from the authors upon request.)

While the results of the first stage regressions are important and provide useful insights, the principal reason for estimating the sample-selection choice models was to generate the Inverse Mills Ratios as explanatory variables in the wheat and corn acreage-supply models for land and pest-management intensity. The IMR for the wheat model was not statistically significant, but it was significant for the corn model (variable Lambda at the bottom of Tables 3 and 4). Therefore, the original GEE parameter estimates were used here for the wheat model, but the revised GEE parameter estimates were used for the corn model.

In addition, Likelihood Ratio statistics for the stage one probit models evaluating the presence of unobserved heterogeneity (for wheat and corn) demonstrate that the models are significant and that there are additional producer education, management, and landscape environmental characteristics important in explaining producer conservation program participation. (Additional discussion and specific statistical results for this endogeneity test are not presented here, but are available from the authors upon request.)

Probit regression results were used to predict the exogenous variable for conservation program participation, separately for the GEE regressions for wheat and corn. The GEE parameter estimates for the acreage-allocation equations by field production system (technology) (Tables 3 and 4), therefore, reflect the adjustment for potential unobserved heterogeneity associated with conservation program participation.

GEE regression results indicate that structural and socio-environmental variables and relative (normalized) prices play different roles in explaining producer choices in land and pest-management intensity across wheat and corn production (Tables 3 and 4).[17] Relative prices play a more important role regardless of program participation in explaining producer adoption of conserving land or conserving pest-management practices for wheat acres than for corn. For corn producers, other variables are apparently more important in explaining differences in land and pest-management intensity (such as use of an irrigation system, the presence of infield and field-perimeter conservation structures, the presence of surface drainage structures, and farm size). Farm size is important in explaining adoption intensity of conserving-land and conserving-pesticide practices for both wheat and corn production.

For wheat producers, relative prices for agricultural wages and diesel fuel explain producer adoption of conserving practices (Table 3). For program participants, relative prices appear to be important in land-management technology adoption decisions [i.e., the adoption of conservation tillage or the use of VRT in seed and fertilizer application, and the use of GPS-based soils maps or nutrient test results]. For program non-participants, relative prices appear to play an important role in pest-management technology adoption decisions.

Relatively higher agricultural wages (ceteris paribus) are positively correlated with pest-management intensity among program non-participants, but negatively associated among conservation program participants. However, an increase in diesel fuel prices (ceteris paribus) has a negative impact on both land and pest-management intensity among program non-participants, but a positive impact on land-management intensity among program participants. These differential effects may be influenced by the fact that conservation tillage and VRTs are more capital-intensive while most conserving pest-management practices are more management (or human-capital) intensive. Therefore, results of an increase in agricultural wages probably reflect a reduction of already

[17] GEE models are non-likelihood based, therefore, the traditional Akaike Information Criterion (AIC) cannot be directly applied. As an alternative, we evaluated the Quasi-likelihood Information Criterion (QIC) (Pan, 2001) for alternative specifications for both the wheat and corn models. Because results did not show significant differences in quasi-likelihood values across alternative models, and in the interest of full disclosure, we present and discuss results for full model specifications for both models.

Table 3
Model I estimated GEE coefficients[a] for wheat field acreage-allocation equations by field production technology (land and pest-management intensity) class, and by conservation program participation.

Equation/variable	Program non-participants		Program participants	
	Estimate	*T*-tests[e]	Estimate	*T*-tests
Constant	2.7868*,[b]	2.85	2.7356[b]	0.34
Wheat field acres planted (using)				
EQ1: conventional production practices[c,d]				
N price	−13.7270	−0.74	−15.9607	−0.46
Ag. wage	−1.4413*	−2.67	0.4010	0.43
Diesel price	13.4630*	2.15	0.0670	0.01
EQ2: conventional production practices with emphasis on conserving Ld. Mgmt. practices				
N price	28.3073	1.01	−143.8377***	−1.60
Ag. wage	0.9655	0.73	−3.4950*	−2.51
Diesel price	−21.2639*	−2.97	55.6199*	2.32
EQ3: conventional production practices with emphasis on conserving Pest Mgmt. practices				
N price	8.2591	0.51	−1.6267	−0.05
Ag. wage	1.2154***	1.70	−2.1363*	−2.32
Diesel price	−18.8146*	−2.53	15.3914	1.28
EQ4: Most conserving production (using both conserving Land and Pest Mgmt. practices)				
N price	6.5341	0.34	44.5754	1.26
Ag. wage	−1.2454	−1.29	−0.5262	−0.61
Diesel price	−12.3859	−1.46	−5.4098	−0.52

	Units	Estimate	*T*-tests
Alternative technology class variables			
Emphasis on land mgmt. practices (A2)	(Yes = 1)	1.4156	0.37
Emphasis on pest mgmt. practices (A3)	(Yes = 1)	2.7421	1.30
Emphasis on conserving land and pest mgmt. practices (A4)	(Yes = 1)	6.7630*	3.17
Other field structural characteristics			
Using conventional irrigation	(Yes = 1)	0.2441	0.97
Using conserving irrigation	(Yes = 1)	0.3948**	1.87
Using only infield structures	(Yes = 1)	0.1032	0.84
Using only field-perimeter structures	(Yes = 1)	−0.0627	−0.29
Using infield and perimeter structures	(Yes = 1)	0.0027	0.01
Socio-environmental variables			
Farm tenure rate	(Owned/operated acres)	0.1706**	1.90
Farm cropland acres	(Acres)	0.0001*	8.43
Gully erosion on field	(Yes = 1)	0.2964*	2.42
Field next to water body	(Yes = 1)	−0.2228***	−1.58
Surface drainage	(Yes = 1)	0.3153*	2.20
Improve wildlife habitat	(Yes = 1)	−0.1440	−0.81
QIC = −1362.7	Lambda (selection bias parameter)	−0.0421	−0.25

Source: 2004 CEAP-ARMS Phase II data (for wheat), Economic Research Service, USDA.

[a] Parameter estimates have been corrected for omitted variable endogeneity associated with conservation program participation. For Model I (for wheat), no adjustment was necessary for sample selection bias.

[b] The constant terms 2.7868 and 2.7356 represent the intercept terms for EQ1 (for the use of conventional production practices), for program non-participants and participants, respectively. Separate intercept terms for the other technology equations (EQ2–EQ4) equal the intercept terms for EQ1, for non-program participants and participants, respectively, plus the coefficients for the alternative technology class variables (A2–A4), respectively.

[c] State average per unit prices (2004) for nitrogen ($/lb), agricultural wage ($/hr), and diesel ($/gal) were normalized using State average 2004 wheat price ($/bu.).

[d] See the *Modeling Approach* section for a description of the alternative production-practice technology classes (conventional vs. more conserving).

[e] Critical values for the t tests are 1.52 (***), 1.76 (**), and 2.14 (*) for the 15%, 10%, and 5% significance levels, respectively. Standard errors were computed using the delete-a-group Jackknife approach (Dubman, 2000).

narrow profit margins while results of an increase in diesel fuel prices likely reflect more of an aggregate production cost effect.[18,19]

For wheat production, other variables influenced land and pest-management intensity decisions. First, adoption of both types of practices as an integrated production technology is an important decision criterion for wheat production. Second, even though use of a conserving irrigation system is important, the presence of other field-level conservation structures do not appear to influence producer decisions on land and pest-management intensity. In other words, integrating land and pest-management practices with field conservation structures (grassed waterways, streamside herbaceous buffers, field borders, etc.) appears not to be a critical decision factor in a wheat producer's land and pest-management intensity decision. Finally, additional socio-environmental factors appear to be more important in intensity decisions for wheat production than they do for corn, with farm-size and the presence of gully erosion on the field being the more significant of these factors. Other socio-environmental factors having a significant influence include a farm's land tenure rate (ratio of owned/operated acres); whether the wheat field is located adjacent to a water body, stream, or wetland; and the presence of surface drainage structures. For both corn and wheat producers, even though farm size appears to play a somewhat stronger role in land and pest-management intensity decisions than do individual field-specific environmental factors, the significance of multiple site-specific environmental factors (particularly for wheat production) highlights the critical importance of accounting for these and other socio-economic factors.

[18] With increased land-management intensity, one would expect a decrease in aggregate fuel cost (for example, due to less tillage), but increased pest-management intensity could increase aggregate wage costs (due to higher skilled labor). For the Northern and Southern Plains States, for wheat production, average 2004 per acre costs ranged between $6.50 and $15.50 for fuel-lube-electricity and about $19.50 for fertilizer. Hired labor costs ranged from $1.80 to $3.00 per acre (USDA-ERS, 2012).

[19] In the interest of saving space, input-price acreage response elasticities are available from the authors upon request.

Table 4
Model II estimated GEE coefficients[a] for corn field acreage-allocation equations by field production technology (land and pest-management intensity) class, and by conservation program participation.

Equation/variable	Program non-participants		Program participants	
	Estimate	*T*-tests[e]	Estimate	*T*-tests
Constant	−1.6136[b]	−0.68	−1.5355[b]	−0.44
Corn field acres planted (using)				
EQ1: conventional production practices[c,d]				
N price	79.0340*	2.29	−62.7597	−0.70
Ag. wage	0.3973	0.88	0.1907	0.23
Diesel price	−11.2788***	−1.55	8.6287	0.52
EQ2: conventional production practices with emphasis on conserving Ld. Mgmt. practices				
N price	−45.8147	−0.83	28.4762	0.33
Ag. wage	−0.2992	−0.45	0.9218	1.06
Diesel price	11.8559	1.09	−9.0398	−0.59
EQ3: conventional production practices with emphasis on conserving Pest Mgmt. practices				
N price	−28.3296	−0.77	50.2737	0.55
Ag. wage	0.4386	1.15	−0.9448	−1.15
Diesel price	3.4061	0.49	−4.0502	−0.23
EQ4: Most conserving production (using both conserving Land and Pest Mgmt. practices)				
N price	27.7932	0.81	−52.3866	−0.94
Ag. wage	0.3075	0.86	0.2635	0.53
Diesel price	−5.9798	−0.98	6.6114	0.64

	Units	Estimate	*T*-tests
Alternative technology class variables			
Emphasis on land mgmt. practices (A2)	(Yes = 1)	0.0828	0.02
Emphasis on pest mgmt. practices (A3)	(Yes = 1)	2.8585	0.84
Emphasis on conserving land and pest mgmt. practices (A4)	(Yes = 1)	4.1794	1.21
Other field structural characteristics			
Using conventional irrigation	(Yes = 1)	0.5495*	2.21
Using conserving irrigation	(Yes = 1)	0.7852*	2.96
Using only infield structures	(Yes = 1)	−0.0079	−0.11
Using only field-perimeter structures	(Yes = 1)	−0.0293	−0.14
Using infield and perimeter structures	(Yes = 1)	0.3202**	1.77
Socio-environmental variables			
Farm tenure rate	(Owned/operated acres)	−0.0236	−0.10
Farm cropland acres	(Acres)	0.0002*	4.15
Gully erosion on field	(Yes = 1)	0.2820	1.31
Field next to water body	(Yes = 1)	0.0429	0.20
Surface drainage	(Yes = 1)	0.3629*	3.15
Improve wildlife habitat	(Yes = 1)	−0.1775	−0.73
QIC = −752.3	Lambda (selection bias parameter)	0.4007*	2.36

Source: 2005 CEAP-ARMS Phase II data (for corn), Economic Research Service, USDA.

[a] Parameter estimates have been corrected for sample selection bias and omitted variable endogeneity associated with conservation program participation.

[b] The constant terms −1.6136 and −1.5355 represent the intercept terms for EQ1 (for the use of conventional production practices), for program non-participants and participants, respectively. Separate intercept terms for the other technology equations (EQ2–EQ4) equal the intercept terms for EQ1, for non-program participants and participants, respectively, plus the coefficients for the alternative technology class variables (A2–A4), respectively.

[c] State average per unit prices (2005) for nitrogen ($/lb.), agricultural wage ($/hr.), and diesel ($/gal.) were normalized using State average 2005 corn price ($/bu.).

[d] See the *Modeling Approach* section for a description of the alternative production technology classes (conventional vs. more conserving).

[e] Critical values for the t tests are 1.52 (***), 1.76 (**), and 2.14 (*) for the 15%, 10%, and 5% significance levels, respectively. Standard errors were computed using the delete-a-group Jackknife approach (Dubman, 2000).

Summary discussion

Since the passage of the 2002 Farm Security and Rural Investment Act, working-land conservation practices have increasingly influenced USDA conservation policy and its traditional land-retirement focus. As a result, policymakers need to improve their understanding of the likely impact of USDA's EQIP and CSP on the economic and environmental stewardship of the farm sector. Development of the USDA CEAP-ARMS surveys reflected recognition of the fact that producers adopt conservation practices for reasons other than program incentives. Identifying the role of other farm structural, technological, and environmental factors in producer adoption of conservation practices helps to clarify the role of program incentives in the adoption decision.

We first used the 2004 and 2005 CEAP-ARMS for wheat and corn to summarize selected characteristic differences between conservation program participants and non-participants, by farm-size typology. We then estimated two cost function based, crop-specific technology adoption models of producer adoption of land and pest-management intensity. Field-level acreage-supply equations were estimated for four land and pest-management technology (intensity) groups for each crop model. Using GEE procedures, each of the model equation systems were evaluated jointly for both conservation program participants and non-participants, with adjustments for sample selection and unobserved heterogeneity biases.

The univariate analysis demonstrates that both wheat and corn farms generally differ significantly by farm-size or program participation, and for some attributes, by both. This implies that wheat and corn farms are heterogeneous across a variety of farm, economic, demographic, and agri-environmental characteristics. Accounting for these attribute differences is important when identifying factors influencing producer adoption of land and pest-management practices, and therefore, in evaluating the benefits of conservation programs.

Univariate results suggest that farms not participating in conservation programs (on their wheat and corn acres) were more frequent users of conservation practices, reflecting both that economics play an important role in farm land and pest management intensity decisions, and that for some producers other social and environmental values also contribute to such decisions. While program participants and non-participants for the 2004 wheat farms tended to use conventional land-management practices, these farms also tended to evenly emphasize the use of conventional and conserving pest-management practices more intensely. However, the 2005 corn farms were somewhat different — program participants and non-participants more evenly emphasized both conventional and conserving land-management practices, while more heavily adopting conserving pest-management practices.

Econometric results provided additional insights into producer adoption of land and pest-management intensity in wheat and corn production. Relative prices, structural, and socio-environmental factors play different roles in their influence on producer technology adoption decisions. While relative prices were important in explaining the intensity of adoption decisions for 2004 wheat production, they were not as useful in explaining similar conserving land and pest-management intensity for 2005 corn production. However for corn, the presence of field-level conservation structures, environmental attributes (such as the presence of surface drainage structures), and farm size appeared to be more important factors explaining producer adoption of conserving land and pest-management practices. Conserving land-management intensity appeared to be the conservation preference for program non-participants, but conserving pest-management intensity appeared to be the conservation preference for program participants. These differences are likely influenced by differences in the capitalization requirements for these investments, with conservation tillage and VRTs for seed and fertilizer application being more physical capital-intensive and conserving pest-management practices being more management (or human capital) intensive.

Non-pecuniary factors also significantly influence producer land and pest-management intensity decisions, but differently for wheat and corn production. For corn production, farm-size and the presence of surface drainage systems on the field were important decision factors, as were producer integration of land and pest-management practices with the use of conservation structures (such as grassed waterways, streamside herbaceous buffers, and field borders). However, integrating land and pest-management practices with conservation structures on the field were not as important for wheat production. Here, socio-environmental factors took on greater significance; in particular, farm-size and the presence of gully erosion on the field appear to be relatively more important in land and pest-management intensity decisions for wheat producers.

Conclusions

Overall, both the univariate and econometric results reveal several important implications for the implementation of U.S. agricultural conservation programs. First, consistent with Bishop et al. (2010) and Sheeder and Lynne (2011), the results here support the need for conservation policy/programs to more formally recognize that economic incentives alone do not determine the entirety of farm land and environmental stewardship. For some farmers, adopting conserving land and pest management practices just makes good business sense (Smith and Weinberg, 2004; Hopkins and Johansson, 2004); for others, moral and social values help to guide their decisions, and yet for others, conservation incentives (financial and/or technical) are required to encourage adoption (Chouinard et al., 2008; Mzoughi, 2011; and Sheeder and Lynne, 2011). Ultimately, however, the environmental effectiveness and cost efficiency of these programs are likely to improve when their implementation recognizes farm heterogeneity.

Second, recognizing differences in farmer motivations for stewardship investments may also require a broader understanding of watershed-level stewardship requirements, as well as how and when to differentiate conservation program incentive structures to meet specific types of conservation program goals. Improved knowledge of the relative influence of farm, economic, crop, and stewardship motivational characteristics of farmers can help improve targeting of available conservation incentive structures (i.e., how to use the appropriate mix of incentive payments, technical assistance, reward structures, and information/educational tools designed to either enhance stewardship awareness or even to encourage it relative to the performance of neighbors). Results from this study suggest the need to refocus program incentives depending on the desired policy goals for the production region of interest. Conservation payments may be more effective for encouraging capital-intensive land-management practices, but technical assistance, reward structures, and extension-oriented information/educational tools may be more effective for enhancing pest-management intensity due to their human-capital orientation.

Recognizing farm heterogeneity, the need to target regionally specific resource conservation practices, and the need to refocus conservation program structures and incentives to meet the objectives of alternative policy goals will be assisted in the future via USDA's new partnership-based, landscape-scale Regional Conservation Partnership Program (RCPP). This program, as part of the Agricultural Act of 2014 (2014 Farm Bill), is designed to help implement USDA resource and conservation programs in a way that further enhances farm land and water stewardship at the watershed/regional landscape scale. It will be accomplished by farmers, along with other resource stakeholders within a watershed or multi-county/state region, forming a partnership with USDA, leveraging federal, state, and local financial resources, to assist producers to install and maintain conservation activities designed to increase the restoration and sustainable use of soil, water, and wildlife and related natural resources across the landscape (USDA-NRCS, 2014).

Finally, to appropriately evaluate the true benefits of agricultural conservation programs, i.e., differentiating between program participant and non-participant behavior, the results here demonstrate that integrating production practice, economic, and site-specific environmental data significantly betters our understanding of the variety of factors that must be considered when evaluating the development and effects of conservation programs.

This study has several limitations. The first relates to the fact that ARMS is a crop-specific survey. As such, ARMS lacks information content on production practices across a farm's cropping pattern, and therefore, our analysis was not able to endogenize cropping pattern within an aggregate farm production system perspective. Secondly, ARMS data is not longitudinal. While these limitations don't distract from the usefulness of the current study's results or their policy implications, they do highlight an awareness of where continued improvements in data linkages across farm, economic, social, and environmental spheres can potentially enhance future conservation program-related analyses.

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Appendix A. Supplementary Data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landusepol.2015.01.018.

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